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# Analysis of Clothes Washer Design Options for their Energy and Water Saving Potential

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# Analysis of Clothes Washer Design Options for their Energy and Water Saving Potential

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***ABSTRACT***

*This paper discusses possible design options for improving the energy efficiency and reducing the water consumption of standard capacity, residential clothes washers. The analysis presented is based on work done for the United States Department of Energy (DOE) as part of their appliance standard rulemaking process. Included in the energy savings shown is the energy required to dry the clothes after washing. Design options are ranked based on both predicted manufacturer costs and energy efficiency.*

## INTRODUCTION

As part of the DOE appliance standard rulemaking process, possible energy saving design options for clothes washers were evaluated based on various technical and economic criteria [1][2]. After possible design options were identified, a preliminary screening was performed to eliminate those clearly not meeting the four criteria outlined in a DOE document sometimes referred to as the interpretive rule [3]. Those design options not eliminated were further evaluated in an engineering analysis, in which costs and energy savings for individual and combinations of design options were determined. The cost and energy data used were primarily obtained from manufacturers through the Association of Home Appliance Manufacturers (AHAM) [4][5]. AHAM calculated shipment weighted averages of design option costs and efficiencies from data submitted by the five major clothes washer manufacturers in the United States in response to a LBNL questionnaire. Shipment weighted averages were calculated so that the manufacturers could avoid making proprietary information public. This data was further adjusted, and ranked by LBNL according to cost/savings ratio. As part of the DOE rulemaking process, the effect of a required energy efficiency level would have on consumers (including payback period and life-cycle cost) and manufacturers is also analyzed, however, this is beyond the scope of this report. Because of DOE's attempt to interact more often and earlier, and receive feedback on design options from all stakeholders, design options can be added or eliminated as new information becomes available.

## PRODUCT CLASSES

DOE differentiates classes by capacity or other performance-related features that provide utility to the consumer and affect efficiency. Currently, clothes washers are separated into the product classes shown in Table 1. The corresponding minimum efficiency requirements which became effective May 14, 1994 are also provided [6].

**Table 1. Current Clothes Washer Product Classes & Efficiency Standards**

| Product Class | Efficiency Standard |
|---|---|
| Compact top loading | EF $\geq$ 0.90 $ft^3$/(kWh/cycle) |
| Standard top loading | EF $\geq$1.18 $ft^3$/(kWh/cycle) |
| Semi-automatic top loading | Must have unheated rinse option |
| Front loading | Must have unheated rinse option |
| Suds saving | Must have unheated rinse option |

For the present analysis, the product classes in Table 2 were considered. In this report only standard capacity clothes washers will be discussed.

**Table 2. Proposed Clothes Washer Product Classes**

| Product Class | Definition |
|---|---|
| Compact | less than 1.6 $ft^3$ capacity |
| Standard | 1.6 $ft^3$ or greater capacity |

## DESIGN OPTIONS

Design options are changes in clothes washer design that may have the potential to save energy.

Table 3 shows the design options initially considered in this analysis.

**Table 3. Design Options**

| |
|---|
| Improved fill control |
| Tighter tub tolerance |
| Added insulation |
| Increased motor efficiency |
| Thermostatically controlled mixing valves (TCMV) |
| Improved water extraction<br>(remaining moisture content; RMC = 50%, 40%, 35%, 30%) |
| Horizontal axis design |
| Horizontal axis with recirculation |
| Advanced controls/sensor (soil load sensor) |
| Suds saving |
| Direct drive motor |
| Automatic fill control |
| Reduced thermal mass |
| Electrolytic disassociation of water |
| Ultrasonic washing |
| Bubble action |
| Ozonated laundering |

The design options listed in Table 4 were eliminated from further consideration because one or more of the four criteria used to pre-screen design options were not satisfied. The four criteria (from the “interpretive rule”) are shown below:

1) Technological Feasibility. Technologies incorporated in commercial products or in working prototypes will be considered technologically feasible.

2) Practicability to Manufacture, Install and Service. If mass production of a technology in commercial products and reliable installation and servicing of technology could be achieved on the scale necessary to serve the relevant market at the time of the effective date of the standard, then that technology will be considered practicable to manufacture, install and service.

3) Adverse Impacts on Product Utility or Product Availability.

4) Adverse Impacts on Health or Safety.

**Table 4. Design Options Eliminated from Further Analysis**

| |
|---|
| Improved water extraction for RMC's of 35% & 30% |
| Suds saving |
| Reduced thermal mass |
| Electrolytic dissociation of water |
| Ultrasonic washing |
| Bubble action |
| Ozonated laundering |

The remaining design options are described below.

<u>Improved Fill Control</u>

This design option is defined as improving the tolerance on existing wash water fill sensing. This can be accomplished by reducing tolerances of presently used pressure sensors or improving switch design. This design option relates primarily to vertical axis design washers, although it is sometimes applicable to horizontal axis washers depending on the specific fill control design. A more accurate water level setting system would avoid overfilling the wash tub, thereby reducing the amount of water and energy used.

<u>Tighter Tub Tolerance</u>

This design option reduces the space (the annulus) between the inner wash basket and the outer tub. This annulus fills with water, but does not add to the clothes washer capacity. Having less space between the inner wash basket and the outer tub reduces the amount of water required for a fill, thereby saving the energy required to heat it. This option applies primarily to vertical axis washers. In a horizontal axis washer, water only occupies the lower portion of the annulus. Since most of the annulus in a horizontal axis washer is filled with air, a smaller annulus does not yield significant energy savings.

### Added Insulation

This design option adds insulation around the outer wash tub to reduce the heat loss around the outer tub. Analysis has shown that there would be little change in the water temperature from adding insulation and therefore little energy savings.

### Increased Motor Efficiency

About 10% of the total electrical energy consumed by a typical clothes washer is used by the electric motor. The typical washing machine has a ½-**b** horsepower motor. One manufacturer states that replacing a split-phase motor with a capacitor start, capacitor run motor may increase the efficiency of the motor by 10% [7].

### Thermostatically Controlled Mixing Valves (TCMVs)

This design option achieves energy savings by more accurately controlling inlet water temperature for hot or warm fills. In a typical non-thermostatically controlled water inlet system, two solenoid valves are used; one valve controls hot water fills while the other controls cold water fills. Both solenoid valves are opened if a warm water setting is selected. In the warm wash mode, a fixed fraction of hot and cold water are controlled by flow control devices. For example, a manufacturer may decide to let warm water be 50% hot and 50% cold. To reduce hot water energy use, some manufacturers have reduced the warm water temperature by using other ratios such as 40% hot and 60% cold.

A thermostatically controlled mixing valve (TCMV) refers to a set of clothes washer valves which sense water temperature and adjust the supply of hot and cold water to maintain a desired warm water temperature.

Energy can be saved with a TCMV by either reducing the hot water temperature or reducing the warm water temperature. For example, the TCMV could be used to lower the hot wash temperature from 135°F to 130°F by mixing hot water (at 135°F test inlet conditions) with cold water. Warm water temperature could be similarly reduced. The energy savings can vary widely depending on the test standard's specified inlet hot water temperature and the selected temperature of the tempered water.

### Improved Water Extraction

There are several ways to reduce the remaining moisture content (RMC) in the laundry load after the final spin cycle. One method is to increase the spin speed of the wash basket for the final spin cycle. Other ways include: 1) changing the direction of rotation to more evenly distribute clothes, 2) having a longer spin cycle, and 3) increasing the size or number of drainage holes in the washer drum. Since mechanical drying is more efficient than using heat to dry, energy consumption for the combined wash and dry process is reduced.

Different spin cycle options would most likely have to be available on a washer to account for the load type. Different fabrics require different maximum spin speeds to avoid clothes damage. The probable, future DOE test procedure (Appendix J1) will most likely assume that the improved water extraction feature will not be used for 25% of the time that the clothes washer is in use. Since this feature can be consumer selectable, clothes subject to wrinkling can be washed with a conventional spin cycle option to avoid a wrinkling problem.

Horizontal Axis Design

Horizontal axis machines rotate the drum (wash basket) and clothes about a horizontal axis. With this design, the drum does not have to be filled with water to cover the top of the clothes. Therefore, horizontal axis machines use much less water than conventional vertical axis machines. In some designs the washer is first filled to a specified level. As clothes absorb the water, a water level sensor allows more water to enter to maintain the specified level. In this way the water level is matched to the laundry load. In laboratory testing, horizontal axis machines used on average 40% less energy and 25% less water when normalized to clothes container volume. The horizontal axis machines also had a greater soil removal effectiveness [8].

Some manufacturers have recommended using less detergent per laundry load than would be needed in a vertical axis design. New information now suggests that if a low sudsing detergent is sold in the U.S., detergent use would remain unchanged [9][10].

Horizontal Axis With Recirculation

This design option is a variation on the horizontal axis design option. It differs in that this design uses a pump to circulate water from a sump underneath the rotating drum through a spray nozzle into the interior of the rotating drum. The small amount of water in the bottom of the drum of a standard horizontal axis washer is not required. Less hot water is needed per wash cycle, thereby saving energy.

Advanced Controls/Sensor (Soil Load Sensor)

According to the proposed future DOE test procedure (Appendix J1), “an adaptive control system refers to a clothes washer control system which is capable of automatically adjusting washer operation or washing conditions based on characteristics of the clothes load placed in the clothes container, without allowing or requiring consumer intervention and/or actions”. This design option would use sensors to measure the soil load and then adjust the wash temperature, agitation and/or tumble cycle time, number of rinse cycles, spin speed, and other parameters. Water and energy use can then be tailored to the load, thereby avoiding washing the clothes more than necessary.

Direct Drive Motor

This design option is primarily intended for use in vertical axis machines. A conventional vertical axis clothes washer uses an induction motor, a mechanical transmission, and sometimes a pulley belt. A direct drive motor can replace a conventional motor/transmission system. Rather than using a belt and/or transmission, a motor could be directly connected to the agitator, thereby avoiding transmission (gearbox) losses.

Automatic Fill Control

This design option incorporates advanced control technologies to sense the clothes load and adjust the water level accordingly. For a vertical axis machine, this may mean setting the water level to just submerge the clothes load. This design option would overcome the tendency of consumers to manually select a water level greater than required.

Energy is saved in either the vertical or horizontal axis designs by reducing the amount of hot water used in the wash cycle. The proposed future (Appendix J1) DOE test procedure (unlike the existing DOE test procedure) uses an actual clothes load and, therefore, possible savings due to this design option can be measured. Washing machines with automatic fill control are available.

High Efficiency Vertical Axis

There are current prototypes and patents describing high efficiency vertical axis clothes washers. These achieve lower energy consumption levels by reducing the amount of water required. Rather than using an agitator they use a nutating disk or other methods to apply mechanical energy to the clothes. One manufacturer states that efficiencies similar to those achieved by horizontal axis machines can be achieved. This design option was identified after the preliminary analysis was performed. Data on cost is not yet publicly available.

## TEST PROCEDURE

The energy and water saving potential were evaluated based on a future DOE test procedure, referred to as version “Appendix J1” [11]. This DOE clothes washer test procedure was proposed in order to more accurately reflect actual energy usage and adapt to the continuing changes in clothes washer design. As in the test procedure currently in effect, assumptions (based on survey data) are made regarding the percentage of time that the consumer will use a hot, warm or cold wash setting. These are referred to as Temperature Use Factors (TUFs). The test procedure also specifies an inlet hot water temperature of 135°F and has provisions to account for adaptive control and automatic fill control. A modified energy factor (MEF) will replace the current energy factor (EF) for standard compliance. (Reporting of the energy factor (EF) will be kept for voluntary programs.) The MEF will include the energy required to dry the clothes, based on the measured remaining moisture content, after the final clothes washer spin cycle. The above changes should result in a more accurate prediction of a the combined clothes washer and clothes dryer energy use.

## ENERGY-USE AND COST ANALYSIS

Manufacturers submitted two sets of cost and efficiency data (through AHAM) with the second set providing additional and in some cases revised data. Information from both data sets were used to generate a cost and efficiency table. Adjustments had to be made to the data submitted by AHAM because 1) not all manufacturers provided data for each design option (adjustments were required due to statistical variations and normalizing) and 2) changes were made to the proposed future test procedure after the data were submitted.

Engineering judgment was used in the cases where LBNL combined individual design options. However, the costs for LBNL combined design options were determined by simple addition of the individual design option costs. The energy-use and MEF values in Table 6 are based on the use of a 100% efficient electric water heater (assuming site energy rather than source energy). Operating expense and dollar savings in energy are based on a weighting of gas and electric water heater and clothes dryer usage and their corresponding fuel costs, as shown in Table 5. Table 5 also shows other parameters used in the energy-use and energy cost calculations.

The energy use and cost of design options, as well as the cost/savings ratio and the annual operating expense, are shown in Table 6. In general, the engineering analysis is based on combining design options starting with the lowest cost/savings ratio. The design option with the lowest cost/savings ratio is then combined with each of the remaining design options. The combination with the lowest cost/savings ratio becomes the first combined desgin option. This process is repeated until all the applicable design options are ranked (i.e., ranked by the lowest cummulative cost/savings ratio). Although this was the basic approach used, where this would limit choices of design options, additional design option paths were "branched off". For example, horizontal axis with recirculating was branched off of the basic horizontal axis path (itself a branch) to enable analysis of the different RMC options with horizontal axis without recirculating. This also allowed for the differences in cost of adding a RMC option to a vertical axis washer and a horizontal axis washer. Table 6 separates the design options into the five basic categories shown below.

- Category a: Vertical axis with RMC design options;
- Category b: Horizontal axis;
- Category c: Horizontal axis with recirculating;
- Category d: Vertical axis with tighter tub tolerance. This was separated from "category a" on the assumption that tighter tub tolerance is not compatible with lower RMC achieved by increasing the spin speed; and
- Category e: Options not analyzed in combination with other design options.

**Table 5. General Assumptions**

| Parameter | Value | Source |
|---|---|---|
| Baseline Clothes Container Volume | 2.9 cubic feet | AHAM |
| Cycles per Year | 392 | DOE test procedure |
| Electricity Price[1] | 0.0836 $/kWh | AEO 1996 [12] |
| Natural Gas Price | 6.075 $/BTU | AEO 1996 |
| Electricity Price Multiplier | 0.90 | LBNL |
| Natural Gas Price Multiplier | 1.01 | LBNL |
| Water and Sewage Cost (U.S. ave.) | 2.84 $/kcal. | Seattle Water [13] |
| Water Heater Efficiency, Electricity | 100% | DOE Test Procedure |
| Water Heater Efficiency, Gas | 75% | DOE Test Procedure |
| Fraction Electric Water Heaters | 0.45 | AHAM [14] |
| Fraction Gas Water Heaters | 0.55 | AHAM |
| Fraction Electric Clothes Dryers | 0.75 | AHAM [15] |
| Fraction Gas Clothes Dryers | 0.25 | AHAM |
| Initial Remaining Moisture Content | 62% | AHAM |
| Dryer Usage Factor (DUF) | 0.84 | DOE Test Procedure |
| Drying Efficiency of Clothes Dryer | 0.5 kWh/lb. | DOE Test Procedure |

[1] Electricity and gas prices are given for the year 2000 in 1994 dollars

## Table 6. Standard Clothes Washer: Cost, Energy-Use, and Water-Use

| No. | Design Option | Incr. Mfr. Cost 1994$ | Total Mfr. Cost[1] 1994$ | Energy-Use: Total Washer kWh/cyc | Dryer[2] kWh/cyc | Total w/ Dryer kWh/cyc | Percent Improv.[3] % | MEF[4] $ft^3/kWh$ | Water Total Gallons gal/cyc | Annual Operating Expense[5] 1994$ | Cost/ Savings Ratio[6] years |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Baseline (vertical axis) | - | 225 | 1.774 | 1.533 | 3.306 | | 0.885 | 38.92 | 117 | |
| 1a | 0 + 50% RMC | 9.60 | 235 | 1.780 | 1.295 | 3.074 | 7.0 | 0.952 | 38.92 | 112 | 1.7 |
| 2a | 1a + Auto Fill + TCMV | 39.78 | 275 | 1.565 | 1.295 | 2.860 | 13.5 | 1.024 | 35.23 | 103 | 3.6 |
| 3a | 1a + Improved Fill Control | 11.58 | 246 | 1.662 | 1.295 | 2.957 | 10.6 | 0.990 | 36.77 | 107 | 2.1 |
| 4a | 1a + 40% RMC | 8.52 | 243 | 1.788 | 1.097 | 2.884 | 12.8 | 1.015 | 38.92 | 107 | 1.8 |
| 5a | 4a + Auto Fill + TCMV | 40.21 | 284 | 1.571 | 1.097 | 2.667 | 19.3 | 1.097 | 35.23 | 99 | 3.1 |
| 6a | 4a + Improved Fill Control | 11.58 | 255 | 1.668 | 1.097 | 2.765 | 16.4 | 1.059 | 36.77 | 102 | 2.0 |
| 1b | Horizontal Axis | 101.5 | 327 | 0.654 | 1.533 | 2.187 | 33.9 | 1.265 | 25.73 | 81 | 2.8 |
| 2b | 1b + Auto Fill | 34.15 | 361 | 0.616 | 1.533 | 2.149 | 35.0 | 1.287 | 25.00 | 79 | 3.6 |
| 3b | 1b + 50% RMC | 8.66 | 336 | 0.665 | 1.295 | 1.960 | 40.7 | 1.411 | 25.73 | 75 | 2.6 |
| 4b | 3b + TCMV | 8.16 | 344 | 0.654 | 1.295 | 1.949 | 41.1 | 1.419 | 25.73 | 75 | 2.8 |
| 5b | 4b + Auto Fill | 31.62 | 375 | 0.601 | 1.295 | 1.896 | 42.7 | 1.459 | 25.01 | 73 | 3.4 |
| 6b | 3b + 40% RMC | 7.49 | 343 | 0.670 | 1.097 | 1.767 | 46.6 | 1.566 | 25.73 | 70 | 2.5 |
| 7b | 6b + TCMV | 8.16 | 351 | 0.659 | 1.097 | 1.756 | 46.9 | 1.575 | 25.73 | 70 | 2.7 |
| 8b | 7b + Auto Fill | 32.05 | 383 | 0.606 | 1.097 | 1.703 | 48.5 | 1.624 | 25.01 | 68 | 3.2 |
| 1c | Horizontal Axis | 101.5 | 327 | 0.654 | 1.533 | 2.187 | 33.9 | 1.265 | 25.73 | 81 | 2.8 |
| 2c | 1c + Horz. Axis w/recirc. | 3.28 | 330 | 0.573 | 1.533 | 2.106 | 36.3 | 1.299 | 21.78 | 75 | 2.5 |
| 3c | 2c + 50% RMC | 8.66 | 339 | 0.584 | 1.295 | 1.879 | 43.2 | 1.456 | 21.78 | 69 | 2.4 |
| 4c | 3c + 40% RMC | 7.49 | 346 | 0.589 | 1.097 | 1.685 | 49.0 | 1.623 | 21.78 | 65 | 2.3 |
| 1d | 0 + Tighter Tub Tolerance | 7.09 | 232 | 1.681 | 1.533 | 3.214 | 2.8 | 0.911 | 36.05 | 112 | 1.4 |
| 2d | 1d + Improved Fill Control | 11.58 | 244 | 1.570 | 1.533 | 3.103 | 6.1 | 0.943 | 34.07 | 108 | 2.0 |
| 3d | 2d + TCMV | 8.16 | 252 | 1.538 | 1.533 | 3.071 | 7.1 | 0.953 | 34.07 | 107 | 2.7 |
| 4d | 1d + TCMV | 8.16 | 241 | 1.646 | 1.533 | 3.179 | 3.9 | 0.921 | 36.05 | 112 | 2.7 |
| 5d | 4d + Auto Fill | 31.62 | 272 | 1.479 | 1.533 | 3.012 | 8.9 | 0.972 | 32.63 | 104 | 3.7 |
| 6d | 1d + Auto Fill | 34.15 | 267 | 1.513 | 1.533 | 3.046 | 7.9 | 0.961 | 32.63 | 105 | 3.4 |
| 1e | 0 + Incr Motor Efficiency | 9.51 | 235 | 1.754 | 1.533 | 3.286 | 0.6 | 0.891 | 38.92 | 117 | 16.1 |
| 2e | 0 + Direct Drive Motor | 70.88 | 296 | 1.640 | 1.533 | 3.172 | 4.1 | 0.923 | 38.92 | 113 | 17.9 |
| 3e | 0 + Advanced Controls | 60.75 | 286 | 1.761 | 1.533 | 3.294 | 0.4 | 0.889 | 38.92 | 117 | 254.0 |
| 4e | 0 + Added Insulation | 48.77 | 274 | 1.774 | 1.533 | 3.306 | 0.0 | 0.885 | 38.92 | 117 | N/A |

[1] Dollar values are shown in rounded dollars; actual values as provided by AHAM are used in all calculations.
[2] Dryer Energy Use ($D_e$) based on 62% initial moisture content. DUF (the ratio of dryer cycles to clothes washer cycles per year) = 0.84
[3] Percent Improvement over the baseline total with dryer energy use.
[4] Clothes Container Volume: Vertical Axis Designs = 2.927 $ft^3$, Horizontal Axis Designs = 2.766 $ft^3$, Horz. with Recirculating Designs = 2.736 $ft^3$; same clothes load capacity is assumed for all design options for purposes of calculating energy use.
[5] Cumulative annual operating cost (based on combined electric/gas water heaters and dryers).
[6] Cost/Savings Ratio = (Change in manufacturer cost relative to baseline) ÷ (Change in annual energy & water cost relative to baseline); (based on combined electric/gas water heaters and dryers).

The headings used in Table 6 are described below.

*Incremental Manufacturer Cost.* This is the cost that would be incurred if the design option were required to meet a minimum efficiency standard and would therefore be mass-produced approximately at the same level as current production levels.

*Total Manufacturer Cost.* This cost is determined by adding a design option incremental cost to the total manufacturer cost of the previous design option.

*Total Washer Energy Use.* This is the sum of the hot water and machine energy use.

*Dryer Energy Use.* This is the amount of energy needed to complete the drying of the test load in a clothes dryer after the final spin cycle.

*Total Energy Use with Dryer.* This is the sum of hot water energy, machine energy, and dryer energy use.

*Percent Improvement.* This is the percent reduction in combined washer and dryer energy use, over the baseline case.

*Modified Energy Factor (MEF).* This is the ratio of washer volume in cubic feet to total energy where the total energy includes the dryer (moisture removal) energy. MEF is given in units of cubic feet per kWh per cycle.

*Total Gallons.* This is the total amount of water used per cycle, both hot and cold.

*Annual Operating Expense.* This is cost in fuel and water to run a washing machine for one year plus the cost to dry the clothes as well. The dollar amount is reported in 1994 dollars.

*Cost/Savings Ratio.* This ratio describes the increase in manufacturer cost for one or more design options relative to the savings in annual operating expense.

## CONCLUSION

Based on the data and analysis shown in Table 6, the combined energy use of washing and drying clothes can be reduced by up to 19% using a conventional vertical-axis design and up to 49% using a horizontal-axis design, with higher spin speed. If only washer energy is considered, vertical axis washer energy savings of approximately 12% and horizontal axis washer savings of 66% can be achieved.

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## REFERENCES

1. U.S. Department of Energy (DOE). 1996a. Proposed Rulemaking Regarding Energy Conservation Standard for Three Cleaning Products. Docket No. EE-RM-94-403. Comment No. 55c *Draft Report on Design Options for Clothes Washers*, October 1996.

2. U.S. Department of Energy (DOE). 1996b. Proposed Rulemaking Regarding Energy Conservation Standard for Three Cleaning Products. Docket No. EE-RM-94-403. Comment No. 55b, *Draft Report on the Preliminary Engineering Analysis for Clothes Washers*, November 15, 1996.

3. U.S. DOE. 1996c. *Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products; Final Rule.* Federal Register Vol. 61, No. 136, Appendix A to Subpart C of Part 430 — July 15, 1996.

4. Association of Home Appliance Manufacturers (AHAM). 1995a. *Comments on the Advance Notice of Proposed Rulemaking*. DOE Docket No. EE RM-94-403, comment #27, May 8, 1995.

5. Association of Home Appliance Manufacturers (AHAM). 1995b. *Comments on the Advance Notice of Proposed Rulemaking*. DOE Docket No. EE RM-94-403, comment #37, June 27, 1995.

6. U.S. Department of Energy (DOE). 1991. *Energy Conservation Program for Consumer Products: Final Rule Regarding Energy Conservation Standards for Three Types of Consumer Products.* Code of Federal Regulations, Title 10 Part 430, Vol. 56, No. 93, May 14, 1991. Docket No. CE-RM-88-101.

7. AHAM. 1995a. *Op. cit.*

8. Arthur D. Little, Inc. (ADL). 1995. *Laboratory Testing of Clothes Washers*, p.3-8, December, 1995, EPRI Report No. TR-105098.

9. A. Cahn. 1994. *The Laundering Process*, handout presented at the Workshop on Home Laundry Energy Standards Regulatory Issues, Washington, D.C., November 11, 1994.

10. Procter & Gamble, *Comments on the Advance Notice of Proposed Rulemaking,* DOE Docket No. EE RM-94-403, comment #9, January 20, 1995.

11. U.S. DOE. 1996d. *Energy Conservation Program for Consumer Products: Test Procedure for Clothes Washers and Reporting Requirement for Clothes Washers, Clothes Dryers, and Dishwashers.* (61 Federal Register 17589, April 22, 1996.), 10CFR, Part 430, Appendices J & J1, Docket No. EE-RM-94-230A.

12. U.S. DOE, Energy Information Administration. 1996. *Annual Energy Outlook 1996 with Projections to 2015*. Washington, D.C., DOE/EA.-0383(96), January.

13. Seattle Water, *Comments on the Advance Notice of Proposed Rulemaking,* DOE Docket No. EE RM-94-403, comment #29, May 8, 1995.

14. AHAM. 1995a. *Op. cit.*

15. AHAM. 1995b. *Op. cit.*